Big Pipestone Creek Sediment Study

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Big Pipestone Creek

Sediment Study

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Summary

Big Pipestone Creek near Whitehall, Montana has long been plagued by channel erosion and sedimentation. Headcuts upstream of two channelized and shortened sections of the creek were known to be significant sources of sediment. At the request of the Jefferson Valley Conservation District, the Water Quality Bureau conducted a sediment source survey on the lower 12 miles of the stream from Interstate 90 to Jefferson Slough. The purpose of the study was to compare sediment production in reaches containing known sources to production in other segments of the creek and a tributary, Little Pipestone Creek.

Instantaneous stream discharge and suspended-sediment concentration were measured monthly from August to October 1981 and from March to June 1982 at 12 sites. Suspended-sediment discharges were computed. Various analytical techniques were used to rank stream reaches according to sediment production for reclamation priority.

The two channelized sections of Big Pipestone Creek ranked first and third. Little Pipestone Creek ranked second when treated as a point source of sediment. An area adjacent to Whitehall ranked fourth. However, dredging in that reach during the study period increased sediment production and may have biased the rating. The other stream sections examined were not problematic.

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Introduction

In 1981 the Water Quality Bureau (WQB) was approached by the Jefferson Valley Conservation District concerning stream channel erosion and sedimentation in Big Pipestone Creek near Whitehall, Montana (Figure1). The district supervisors expressed concern that the problems were contributing to a reduced channel capacity and more frequent flooding in and around Whitehall, and that the high sediment loads were contributing to sedimentation in the Jefferson Slough into which Big Pipestone Creek flows. A major source of the sediment was considered to be serious headcutting and bank sloughing which was evident upstream of two channelized sections of the creek.

The same year, the WQB approved a grant to the district in order to evaluate the feasability of stabilizing the major headcuts and reclaiming the channelized sections of Pipestone Creek. The district hired a contractor who assessed these hydrological problems and made recommendations for their correction. The report of that investigation (Hanson, 1982) was completed in July 1982, which was after the WQB finished the field work for this study.

A visual survey of the creek during high flow in 1981 indicated that Little Pipestone Creek and some segments of Big Pipestone Creek above the channelized sections may be significant sources of sediment in addition to the headcuts. To help the district focus on other sediment producing areas and to determine how sediment production from those reaches compared to the known problem areas, the WQB established twelve suspended sediment and discharge monitoring stations in the drainage (Figure1). It was anticipated that an analysis of suspended-sediment discharges would identify stream reaches contributing significant quantities of sediment.

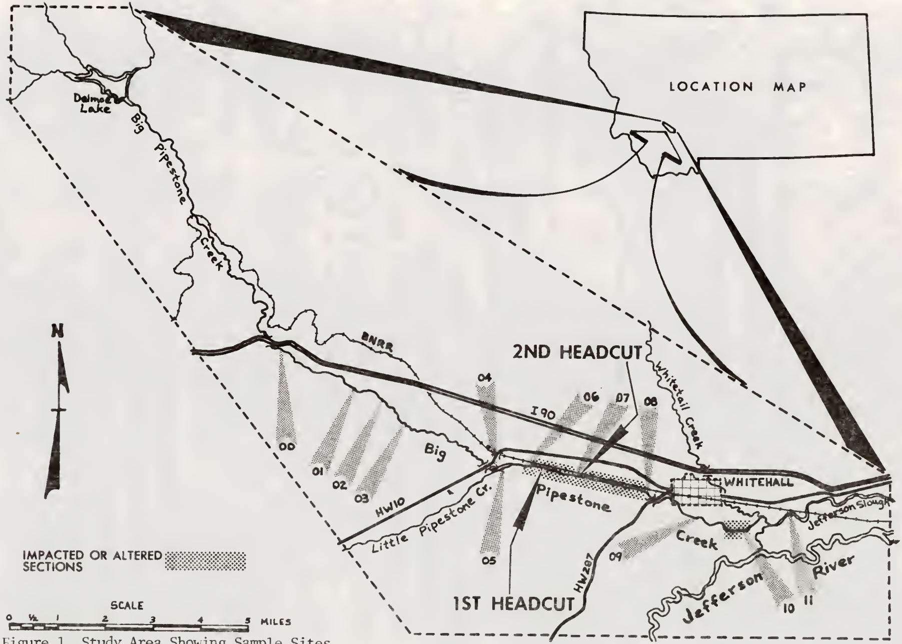


Figure 1. Study Area Showing Sample Sites and Impacted or Altered Stream Reaches.

The WQB could then work with the district to determine if apparent sediment sources in reaches of high pick up could be reclaimed with better land management practices, or if the sources were natural and channel/bank conditions acceptable.

Methods

Ten suspended-sediment and stream discharge stations were established in the Big Pipestone drainage. Site selection criteria were ease of access and locations of potential problem areas as identified during the visual survey. Nine stations were located on Big Pipestone Creek and one was established on Little Pipestone Creek near its mouth. Two additional stations were added later. One of these was on Big Pipestone Creek upstream of the others and where the creek first enters the Jefferson River Valley just downstream from Interstate 90. This station served as a control as it was upstream of any erosion originating in the valley. It allowed measurement of background sediment levels originating in the stream's headwaters in the granitic batholith of the Deer Lodge National Forest. The other station was added on the Jefferson Slough downstream from the mouth of Big Pipestone Creek in order to investigate the suspected sedimentation problem there.

Locations of the twelve monitoring stations in relation to the impacted or altered stream sections are depicted in Figure 1. Station descriptions and map coordinates are given in Table 1.

Suspended-sediment concentrations were measured to allow quantification of the suspended-sediment discharge at the sample sites. Bed load, which contributes the remaining portion of a stream's total sediment discharge, was not measured due to lack of equipment and expertise. Suspended-sediment

Table 1. Sample Site Descriptions and Map Coordinates

No	Description	Map Coordinates
00	Big Pipestone Creek just downstream of Whiskey Gulch	T2N R5W Sec 19 Tract BD
01	Big Pipestone Creek at Pipestone Hot Springs	T2N R5W Sec 28 Tract CA
02	Big Pipestone Creek 0.75 mile downstream of Hot Springs	T2N R5W Sec 28 Tract DD
03	Big Pipestone Creek 1.5 miles downstream of Hot Springs	T2N R5W Sec 34 Tract AB
04	Big Pipestone Creek at HW 10 crossing	T2N R5W Sec 35 Tract DC
05	Little Pipestone Creek near mouth	T2N R5W Sec 35 Tract DC
06	Big Pipestone Creek just downstream of Little Pipestone Creek	T2N R5W Sec 35 Tract DD
07	Big Pipestone Creek 2.5 miles west of Whitehall	T2N R4W Sec 31 Tract CD
08	Big Pipestone Creek just west of Whitehall city limits	T1N R4W Sec 04 Tract BB
09	Big Pipestone Creek just south of Whitehall city limits	T1N R4W Sec 03 Tract CB
10	Big Pipestone Creek just upstream of Whitehall STP* discharge	T1N R4W Sec 03 Tract CB
11	Jefferson Slough just downstream of Whitetail Creek	T1N R4W Sec 03 Tract DD

* Sewage treatment plant

samples were collected and stream discharge measured monthly during August, September, and October 1981. Monthly sampling was resumed in March 1982 and continued through June.

Current velocity was measured with a Marsh-McBirney Model 201 portable water current meter. A straight section of stream with a uniform cross-section and a smooth streambed was chosen whenever available. A measuring tape was stretched across the channel and depths and velocities were recorded at selected points such that no more than ten percent of the total discharge fell between two consecutive points. Total instantaneous discharge was then calculated by summing discharges for each of the measured subsections. Flows were estimated during June 1982 at several stations which could not be waded.

One pint suspended-sediment samples were collected with a depth-integrating type DH-48 sampler with a 0.25 inch orifice. Using the measuring tape from the discharge measurement, the sampler was lowered from the water surface to the streambed and back at the same rate at ten to twenty equally spaced points in the stream cross section, depending on stream width. This equal- width increment or EWI method (USGS, 1977) provides a water/sediment sample that is discharge-weighted both vertically and laterally.

Samples were transported unpreserved to the Montana Department of Health Chemistry Laboratory Bureau in Helena. Suspended-sediment concentrations were measured gravimetrically following filtration and evaporation at 105°C (EPA, 1979).

Suspended-sediment concentrations and instantaneous stream discharges were used to compute suspended-sediment discharge in tons per day.

Channel slope (stream gradient) was computed to examine its effect on erosion and deposition of sediments between stations. First stream mileage between sites was measured from aerial photographs and U. S. Geological Survey topographic maps. Elevations at the sample sites were determined from the topographic maps and from data obtained by Hanson (1982) by differential levelling. Channel slope was then computed as vertical drop (in feet) over distance (in stream miles). Because of the small scale of the aerial photographs and maps, stream mileages were probably underestimated resulting in overestimations of slope for each stream reach. However, most sediment moves during high flows and at that time the stream "thread" is actually straightened over that of low water conditions. Thus, the channel slope as computed probably is quite adequate to describe the Big Pipestone Creek gradient during heavy runoff. (D. R. Reichmuth, pers. comm., January 1983).

Results

Mean and individual values for stream discharge, suspended-sediment concentration and computed suspended-sediment discharge are given in Appendix A. Figure 2 depicts mean, minimum and maximum suspended-sediment concentration and suspended-sediment discharge for each site. Figure 3 graphs suspended-sediment discharge in a downstream progression on each sampling date. Figure 4 shows seasonal variation in suspended-sediment discharge and stream discharge for each site. April, May and June averages of net suspended-sediment production between sites and per stream mile are plotted in Figure 5, the intention being to illustrate the relative seriousness of erosion in each stream reach during spring runoff. Stream mileage and computed channel slope between sample sites are tabulated in Appendix B. Raw data used in the formulation of Figure 5 are listed in Appendices C and D.

Limitations and Assumptions

The evaluation of a sediment problem "usually requires measuring the quantitative and qualitative character of sediments suspended in, transported by, and deposited from....streams" (USGS, 1978). In order to use suspended sediment as an indicator of total sediment carried by a stream at a particular location, one must consider the nature of alluvial sediments and their modes of transport and then make certain assumptions regarding these phenomena in Big Pipestone Creek.

Typically, the sediment discharge of a stream increases with increasing distance from the stream's source. This is due primarily to the fact that drainage area, available sediment sources and stream discharge tend to increase in a downstream direction. Also, the geology of the terrain through which the stream channel flows plays an important part; many streams head in the relatively stable and rocky soils of the mountains and then descend to the more erosive soils of the valley floor. In natural, unimpacted systems, such changes rarely occur quickly or over short distances. The trend is usually one of gradually increasing sediment discharge over many stream miles. And in some cases, the entrance of cleaner tributaries or the influences of dams, reservoirs or lakes may temporarily reduce the quantity of sediment carried by a stream.

Since Big Pipestone Creek originates at the outlet of Delmoe Lake, an irrigation reservoir, its sediment discharge will initially be quite small because the reservoir will tend to precipitate the sediment loads of the several tributaries which feed it.

The sediment discharge of a stream consists of both fine and coarse particles. Fine particles (<0.062 mm dia.) are easily suspended by natural stream turbulence and travel through the system at about the same velocity as the water (Guy, 1966 In USGS, 1977). Coarse particles (>0.062 mm dia.), on the other hand, are transported both as suspended material and bedload--sediment moving on or near the bottom. Individual coarse particles move whenever the lift and drag forces or the impact of another moving particle overcome the particle's inertia and dislodge it from its resting place; the particles move in a series of steps interrupted by periods of no motion. Rates of movement depend upon many factors, including the properties of the water, the sediment, the flow and the channel geometry (Colby, 1961; Colby, 1964; Leopold and Maddock, 1953 In USGS, 1977). As a result, the bedload portion of the total sediment discharge observed at one stream cross section may not be the same as that at another cross section up or downstream. The same is true for the suspended portion.

Given the above, we must first assume that if channel slope generally declines in a downstream direction, as it does in Big Pipestone Creek (See Appendix B), average current velocity will in turn decrease. And as current velocities decrease, a lesser quantity of (coarse) sediment will remain in suspension and more will become part of the bedload. Thus, significant downstream increases in suspended-sediment concentration throughout the Big Pipestone Creek study reach should be related to new sediment sources and not to the suspension of material which was part of the bedload immediately upstream.

Secondly, as Big Pipestone Creek travels from its headwaters to the Jefferson River Valley, the average size of particles making up the sediment load should become smaller because the available sediment sources will change from decomposing granite and sandy mountain soils to better developed valley soils with larger proportions of clay and silt. Hence, problematic erosion in the valley reaches of Big Pipestone Creek will produce a finer sediment that will likely show up in the suspended fraction. Thus, for the purposes of ranking the stream reaches, we can assume that the severity of the erosion and sedimentation problem is roughly proportional to the measured changes in suspended-sediment concentration and suspended-sediment discharge.

Lastly, due to the limited frequency of measurements during the course of this investigation, the sediment data contained herein probably do not accurately quantify the range of sediment concentrations or the magnitude of annual Big Pipestone Creek sediment loads but should be used only for comparisons between sample sites or stream reaches.

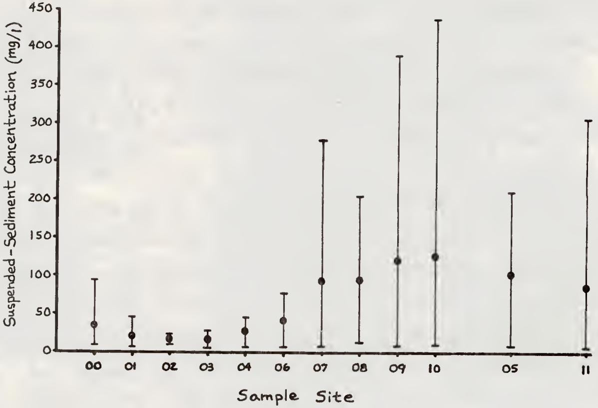
Explanation of Figures

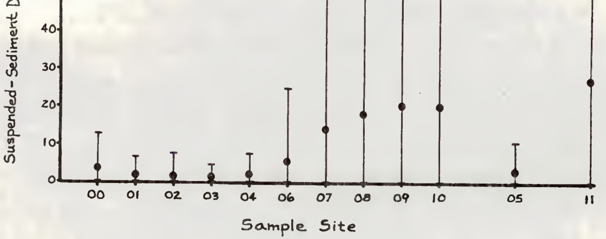
The following is a stepwise interpretation of Figures 2 through 5:

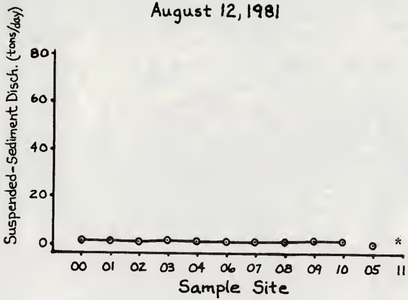
Figure 2.

On Pipestone Creek, mean suspended-sediment concentration follows nearly the same trend as suspended-sediment discharge. On nearly every sampling date, both concentration and discharge declined from the control site to the second site (00 to 01). This is probably due to changes in channel slope. Between the first two sites, channel slope was much higher than in the lower reaches (See Appendix B). The suspended-sediment discharge at the control site appeared to consist of larger material in the form of pyrite and granitic sands. The gradient decreased rapidly downstream of Site 01 and this may explain how the coarser particles at the control site could be deposited or

Figure 2. Mean, Minimum and Maximum Suspended-Sediment Concentration (mg/1.) and Suspended- Sediment Discharge (tons/day) for August-October 1981 and March-June 1982.







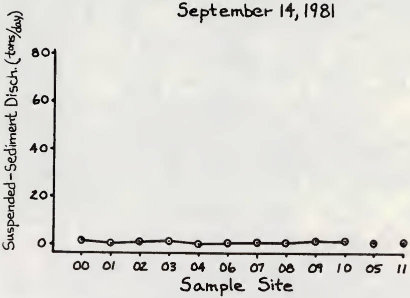
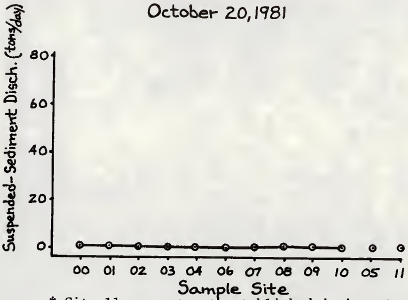
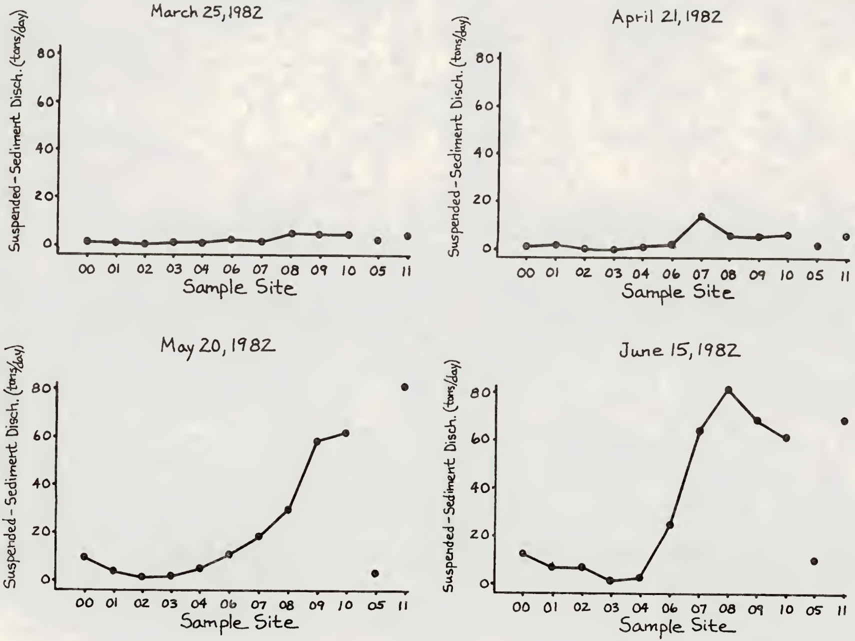


Figure 3. Suspended-Sediment Discharge (tons/day) on Each Sampling Date.



* Site 11 was not yet established in August. No measurements were performed.

Figure 3. (cont'd.)



Fibure 4. Seasonal Variation in Suspended-Sediment Discharge (tons/day) and Stream Discharge (cfs) at Each Sample Site.

-----------Suspended- Sediment Discharge

__________Stream Discharge

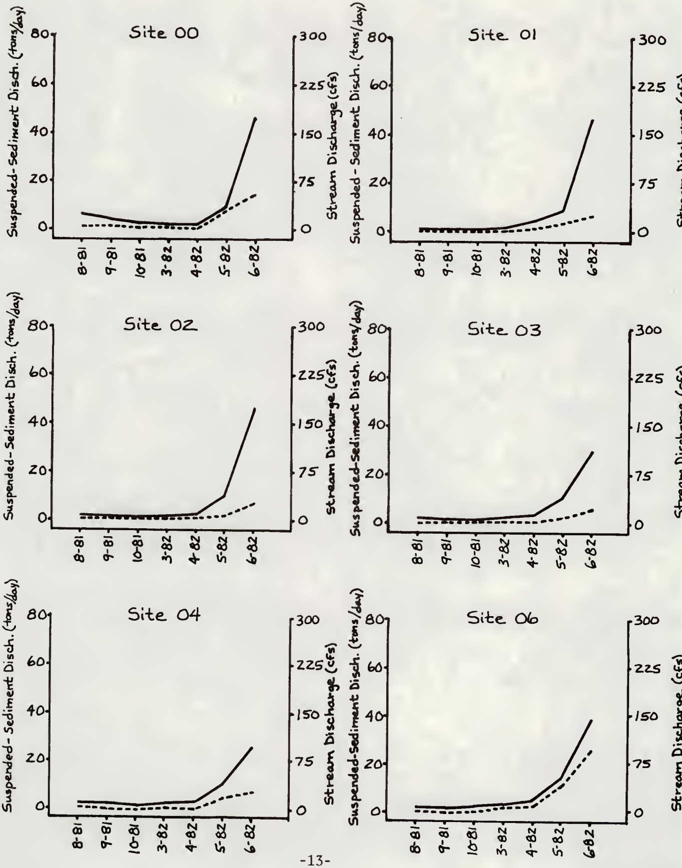


Figure 4. (cont'd.)

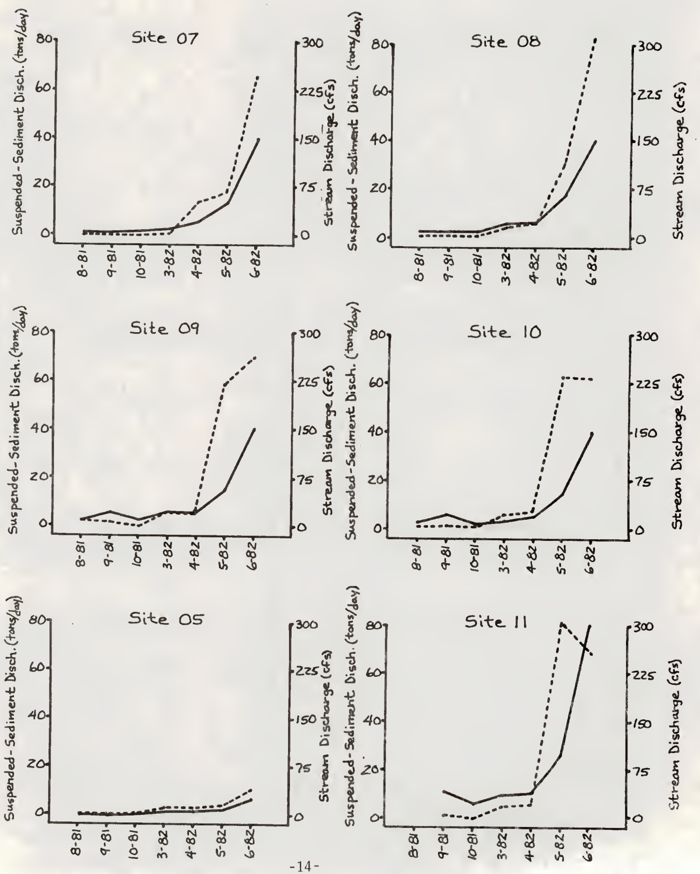
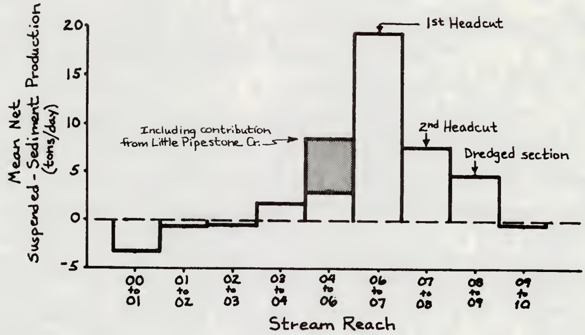
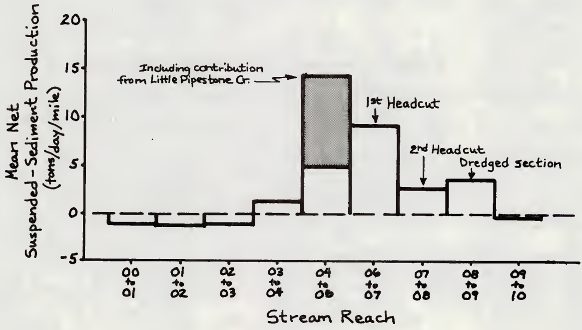


Figure 5. Mean Net Suspended-Sediment Production (tons/day and tons/day/stream mile) By Stream Reach.





* Means computed on basis of April, May and June measurements. See page 18 for explanation.

become part of the bedload. That would account for the measured reduction in suspended sediment at Site 01. Beginning at Site 01 the suspended-sediment discharge appeared to consist predominantly of a finer clay-like material.

Following this initial reduction in mean suspended-sediment concentration and suspended-sediment discharge was a gradual and then a more abrupt increase despite a frequently observed downstream decrease in stream discharge due to irrigation withdrawals (See Appendix A). The mean suspended-sediment discharge in Big Pipestone Creek peaked at Site 09, while concentration peaked at Site 10. The Jefferson Slough (Site 11) carried the highest average suspended-sediment discharge of sites monitored due to its generally large stream discharge while its average suspended-sediment concentration was comparable to the lower four stations on Big Pipestone Creek. Average suspended-sediment concentration in Little Pipestone Creek (Site 05) was high compared to other sites. Its suspended-sediment discharge, however, was rather low because of its small stream discharge in relation to Big Pipestone Creek.

While the trend displayed by mean suspended-sediment concentration and suspended-sediment discharge is not particularly significant, the ranges of the individual values may be. Note that for both concentration and discharge, the ranges at upstream sites on Big Pipestone Creek are relatively narrow. Progressing downstream, concentration and discharge began to fluctuate widely. The data in Appendix A indicate that the fluctuations at downstream sites are seasonal in nature and they correlate directly with stream discharge. The range of suspended-sediment concentrations measured at Site 02

was the narrowest; individual values varied by no more than about 100 percent despite fluctuations in stream discharge which amounted to more than 5000 percent. On the other hand, at Site 10 suspended-sediment concentrations varied by more than 4200 percent while measured stream discharge varied by less than 1300 percent. Thus it would seem reasonable to use the range of suspended-sediment concentrations and discharges as an index of stream channel stability. Wide fluctuations in the range of measurements may indicate problem areas which tend to contribute significant quantities of sediment under high flows. If this approach is indeed reasonable it appears that problems first begin below Site 04 and increase in severity downstream. Little Pipestone Creek had a wide range of suspended-sediment concentrations but surprisingly the suspended-sediment discharge was rather constant. Jefferson Slough sediment concentrations and sediment discharges fluctuated widely, like the lower Big Pipestone Creek stations.

Figure3. The seven graphs of suspended-sediment discharges at the various sites on the different sampling dates show that the erosion problems on Big Pipestone Creek and the Jefferson Slough are highly seasonal in nature because of streamflow. Very little downstream increase in suspended-sediment discharge was measured during the low flow months of August, September, October, and March. In April, a significant jump in suspended-sediment discharge occurred between Sites 06 and 07 possibly indicating a problem area in that stream reach. During the high streamflow months of May and June, significant quantities of sediment were moved. It is also apparent that most of the erosion occurred downstream of Site 04, with the peak suspended-sediment discharge in June being measured at Site 08.

As in Figure 2, an initial decline in suspended-sediment discharge is observed between the control site and several successive stations. Again,

this may be attributable to a decreasing channel slope, deposition of coarse particles and no significant new sediment sources.

Little Pipestone Creek showed seasonal increases in suspended-sediment discharge related to stream discharge. However the variation was not of the magnitude seen at lower Big Pipestone Creek stations.

Figure 4. The twelve graphs in Figure 4 show changes in suspended-sediment discharge at each sample site as a function of stream discharge. An important conclusion can be drawn from examination of the individual plots. As stream discharge increased in the spring months at the upper sample sites, suspended-sediment discharge did not increase proportionately, but lagged well behind. Progressing downstream to Site 06, suspended-sediment discharge began to climb with stream discharge. At the lower four Big Pipestone Creek Stations, 07 through 10, suspended-sediment discharge actually increased at a greater rate than did stream discharge, beginning in March or April. Thus it appears that those reaches were the most significant in terms of sediment production per unit of stream discharge. Suspended-sediment discharge in Little Pipestone Creek (Site 05), although of a smaller magnitude than at other stations, tended to directly follow the pattern of stream discharge throughout the period of study. Site 11, the Jefferson Slough, followed a pattern similar to the lower Big Pipestone Creek stations, no doubt a result of the influences of the creek's suspended-sediment discharge on the Slough.

Figure 5. The two bar graphs show mean net suspended-sediment production by stream reach, that is, actual sediment mobilization in the stream reach that was not attributable to any sediment being passed through at the same time from upstream. Means are based on April, May, and June measurements only because, as we saw in Figure 4, these are months of significant sediment

production. Inclusion of all data tended to depress peaks and make interpretation more difficult. The upper graph shows suspended-sediment production regardless of the length of the stream reach and thereby depicts the overall severity of the erosion problem in that reach. The lower graph shows suspended-sediment production in each reach per stream mile.

The graphs show the rank of the different reaches in terms of severity of suspended-sediment production; the higher a bar falls above the zero axis on the graph, the greater the suspended-sediment production that was measured in the stream reach during the three months. And according to our earlier rationale (p.8), it can be assumed that the suspended-sediment production is roughly proportional to the severity of the erosion problem.

The upper graph shows that the reach between Sites 06 and 07 far surpasses all others in terms of severity. Not surprisingly this reach brackets the first headcut described by Hanson (1982) and is at the upper end of a major channel change.

The second most severe reach is between Sites 04 and 06 when the sediment contributions from Little Pipestone Creek are included. The lower, unshaded portion of the bar shows how the stream reach compares if the suspended-sediment discharge measured at Site 05 (Little Pipestone Creek) is subtracted from that measured at Site 06. Thus, Little Pipestone Creek is a significant source of sediment to Big Pipestone Creek. If the suspended-sediment discharge of Little Pipestone Creek is not considered, the stream reach between Sites 04 and 06 does not appear to be especially problematic under this scheme.

The third worst section brackets the second headcut described by Hanson (1982). Surprisingly the stream reach between Sites 08 and 09 ranks fourth.

This reach is in the area described by Hanson (1982) as not being troubled by erosion but rather by deposition of the eroded material in the stream channel, along the banks and on the flood plain. This is the expected cause of the flooding problem and elevated water table in and around Whitehall. The apparent high suspended-sediment yield here may be explained by the fact that prior to the May 20 sampling trip, the owner of the land adjacent to Site 09 dredged and deepened the stream channel in an attempt to reduce the threat of spring flooding. Heavy equipment in the stream and the destruction of riparian vegetation resulted in the destabilization and increased erosion of the streambed and banks. At the time of our visit a few days after these activities, suspended-sediment concentrations jumped from 185 mg/l to 390 mg/l from Site 08 to 09. Based on earlier and later measurements, such increases were not typical for the reach. Thus the temporary increase in sediment production tended to skew the mean, which resulted in a falsely high severity ranking.

The stream segment between Sites 03 and 04 ranked lowest of the sediment producing reaches. The remaining three upper reaches were areas of net sediment deposition.

The lower graph may be more meaningful from the standpoint of reclamation feasability because it allows a ranking of stream reaches according to suspended- sediment production per unit length of stream channel. Thus, resource managers will be able to determine where greatest returns can be expected in terms of reduced erosion and improved water quality per unit length of stream channel reclaimed.

This graph, like the upper one, ranks the stream reach bracketing the first headcut as the most severe. The mean suspended-sediment contribution of this reach, based on three spring measurements, amounted to more than nine tons/day/stream mile.

The shaded portion of the bar shows where net suspended-sediment production in the reach from Site 04 to 06 would be plotted if the contributions from Little Pipestone Creek were included; it would rank number one in terms of severity if Little Pipestone Creek were treated as a point source of sediment. However, from the standpoint of corrective action, one must consider that the Little Pipestone Creek sediment discharge is probably generated over many miles and reduction of the problem could be expensive and difficult. Referring to the unshaded portion of the graph, the reach from Site 04 to 06 ranks second if the measured suspended-sediment discharge contributed by Little Pipestone Creek is subtracted. This observation leads one to believe that the Big Pipestone Creek channel in this reach has a significant erosion problem. The author, however, feels that what we are seeing is a mobilization of sediments during higher spring flows that were deposited in the reach by Little Pipestone Creek during low flows. This is referred to as "channel flushing." A review of the data in Appendix A supports this conclusion. With the exception of May and June, the suspended-sediment discharge at Site 06 was significantly less than the combined suspended-sediment discharges of Sites 04 and 05. Thus, deposition had to occur between Sites 04 and 06. In May and June, suspended-sediment discharge at Site 06 was roughly 50 percent more than the combined discharges of Sites 04 and 05; the sediment deposits were beginning to move in response to higher flows.

The stream reach betweeen Sites 08 and 09, ranked third in terms of net suspended-sediment production per stream mile. As with the upper graph, the channel disturbance through the reach upstream of Site 09 probably accounts for its high rank.

The fourth most severe segment, between Sites 07 and 08 and in the vicinity of the second headcut, would probably have surpassed it had the disturbance not occurred.

The reach between Sites 03 and 04 ranked fifth, the same ranking it had under the first scheme. The first four sampling sites on Big Pipestone Creek did not reflect a sediment source which might be problematic.

Suspended-sediment production or deposition in the Jefferson Slough could not be ascertained because Site 11 was the only station on this stream. Combined contributions from Big Pipestone Creek and Whitetail Creek (which enters Big Pipestone Creek between Site 10 and its mouth) were not determined.

The reaches are ranked in Table 2 according to their net production of suspended-sediment. Three rankings are given: one based on net suspended-sediment production throughout the reach regardless of length, one based on net suspended-sediment production per mile within the reach, and one in which the rankings are adjusted as discussed in the following section.

Conclusions

The adjusted severity ranking given in Table 2 was synthesized from the two analysis schemes presented in Figure 5 with slight modifications based on field observations and the other data. This ranking and other conclusions of the study are listed below:

1) All the data point to the stream reach between Sites 06 and 07, the first headcut, as being the most problematic in the study area in terms of sediment production.

2) When treated as a point-source of sediment, Little Pipestone Creek ranked second as a critical sediment source. The data suggest that much of the suspended-sediment discharge contributed by Little Pipestone to Big Pipestone Creek may have been deposited within a

Table 2. Ranking of Stream Reaches by Sediment Production*

Overall Severity Based on Sediment Production Throughout Entire Reach

1) Stream channel between Sites 06 and 07
2) Stream channel between Sites 04 and 06 (incl. contributions from Site 05)
3) Stream channel between Sites 07 and 08
4) Stream channel between Sites 08 and 09
5) Stream channel between Sites 03 and 04

Severity Based on Sediment Production Per Mile of Stream Channel

1) Stream channel between Sites 06 and 07
2) Stream channel between Sites 04 and 06 (excl. contributions from Site 05)
3) Stream channel between Sites 08 and 09
4) Stream channel between Sites 07 and 08
5) Stream channel between Sites 03 and 04

Adjusted Final Ranking

1) Stream channel between Sites 06 and 07
2) Little Pipestone Creek drainage
3) Stream channel between Sites 07 and 08
4) Stream channel between Sites 08 and 09
5) Stream channel between Sites 03 and 04

*Ranking based on mean of April, May and June suspended-sediment discharges.

short distance during low-flow months and at such times impacts downstream were probably minimal. During higher flows however, the deposits were mobilized and there is little doubt that they contributed to the problems documented in the downstream reaches.

3) The stream reach bracketing the second headcut (from Site 07 to 08) was rated as the third most severe sediment-producing area. Its problems approached the severity of Little Pipestone Creek.

4) Although it was rated more severe than the second headcut under one scheme, the reach from Site 08 to 09 was given a final ranking of four because of the observed effects of the dredging activity on the sediment data. The author has reservations about rating this reach because according to Hanson (1982), this is an area of deposition. The appreciable suspended-sediment levels measured during higher flows may have reflected the mobilization of material deposited in the reach during lower flows, but which originated upstream.

5) The area between Sites 03 and 04 apparently contributed some sediment to the Big Pipestone Creek system, however it did not appear to be critical. As a result of the observed deposition of sediments between the control site (site 00) and the three successive downstream sites (Sites 01, 02 and 03) as shown in Figure 5, the sediment production from Sites 03 to 04 might reflect the movement of some of that material under higher flows in addition to any in-channel production.

6) The stream reach between Site 00 and 03 appeared to be an area of net suspended-sediment deposition and problems were not suggested.

7) The suspected sedimentation problem in the Jefferson Slough could not be adequately ascertained from this study due to a lack of monitoring sites on Whitetail Creek and on the Slough upstream of the Big Pipestone Creek mouth. However, field observations clearly indicated a a net deposition of coarse granitic sediments on the stream bottom.
8) The other data presented herein indicate that during the study period of August 1981 to June 1982, the erosion problem in Big Pipestone Creek was only significant during spring runoff from April to June.

Recommendations

Should the Jefferson Valley Conservatin District decide that reclamation of problematic stream reaches in the Big Pipestone Creek drainage is desirable and adequate funding is located, the WQB makes the following recommendations:

1) The stream reach in the vicinity of the first headcut should be reclaimed first. Compared to the other problem areas, the greatest returns in terms of reduced erosion and improved water quality in the Big Pipestone Creek drainage will be realized by pursuing corrective measures there.
2) The data suggest that Little Pipestone Creek should be the number two reclamation priority. However, it is suspected that the sediment sources in that drainage may be diffuse. Correction of the problem could be difficult and expensive. Conversely, the second headcut is a localized problem and the sediment production associated with it is not a great deal less than that of the entire Little Pipestone Creek drainage. Therefore, it would be prudent to focus on the stream reach in the vicinity of the second headcut as the second reclamation priority.

3) The Jefferson Valley Conservation District should conduct a visual survey of Little Pipestone Creek to determine if the sediment production in that drainage is natural or man-caused. If it is man-caused, the District should work with the land owners to implement improved land-use practices.

4) If corrective measures are applied in the above mentioned areas, it would be desirable after a period of time to reevaluate the implied erosion problems in the stream reach from Site 08 to 09. It is likely that further monitoring would show that the suspended solids levels measured in that reach during this study had indeed originated at the problem areas upstream.

5) Reclamation efforts do not appear to be warranted in the remaining portions of the study area at this time.

6) There is little doubt that stabilization of the headcuts would be a beneficial and cost-effective endeavor, but one is cautioned against over-optimism. Even with sediment control measures at the headcuts, significant sediment production in the form of bedload is likely to occur in the Big Pipestone Creeek drainage as a result of the natural erosion of the granitic batholith areas of the headwaters. The significant sediment production in the form of bedload is likely to occur in the Big Pipestone Creeek drainage as a result of the natural erosion of the granitic batholith areas of the headwaters. The produced granite sands will continue to be deposited in portions of Big Pipestone Creek and in the Jefferson Slough because of its naturally flat gradient. A continuance of the problems presently associated with the sedimentation in lower Pipestone Creek and the Slough is entirely possible, although they would certainly be of a reduced magnitude.

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Appendix A. Stream Discharge (cfs), Suspended-Sediment Concentration (mg/l) and Computed Suspended-Sediment Discharge

Monitoring Stations

	00	01	02	03	04	05	06	07	08	09	10	11
Date	8-12-81											
Stream Discharge	21.3	4.1	4.7	9.3	10.1	0.52	6.2	3.4	9.9	11.5	12.6	-
Suspended-Sediment Conc.	9.1	4.6*	18.	23.5	25.3	30.9	22.6	17.8	38.	27.7	10.4	-
Suspended-Sediment Discharge	0.52	0.05	0.23	0.59	0.69	0.04	0.38	0.16	1.01	0.86	0.35	-
Date	9-14-81											
Stream Discharge	15.2	3.8	5.2	5.6	7.0	0.14	4.2	2.1	8.4	18.4	18.0	41.9
Suspended- Sediment Conc.	17.7	8.1*	22.2	15.3	3.3*	4.5*	5.4*	4.1*	17.1	27.3	19.9	9.6
Suspended-Sediment Discharge	0.72	0.08	0.31	0.23	0.06	<0.01	0.06	0.02	0.39	1.35	0.96	1.08
Date	10-20-81											
Stream Discharge	7.0	2.1	3.2	3.8	2.8	1.9	7.8	6.3	11.1	10.9	11.7	25.4
Suspended-Sediment Conc.	13.9	3.4*	10.4	2.5*	3.0*	10.8	5.0*	3.4*	12.5	8.7	12.0	5.5*
Suspended-Sediment Discharge	0.26	0.02	0.09	0.02	0.02	0.06	0.10	0.06	0.37	0.26	038	0.38
Date	3-25-82											
Stream Discharge	5.7	7.8	6.0	9.3	8.0	4.9	13.2	12.8	17.5	16.9	14.7	34.2
Suspended-Sediment Conc.	57.2	18.6	23.	28.3	26.1	219.	66.4	43.4	96.2	115.	117.	46.5
Suspended-Sediment Discharge	0.88	0.39	0.37	0.71	0.56	2.89	2.36	1.49	4.53	5.23	4.63	4.28
Date	4-21-82											
Stream Discharge	7.3	16.0	11.9	12.5	10.8	6.3	17.0	18.2	20.4	20.7	19.9	43.6
Suspended-Sediment Conc.	27.9	36.6	11.0*	9.2*	19.2	198.	53.4	277.	112.	103.	128.	60.2
Suspended-Sediment Discharge	0.55	1.58	0.35	0.31	0.56	3.36	2.44	13.56	6.15	5.74	6.85	7.06
Date	5-20-82											
Stream Discharge	35.3	32.2	37.7	39.0	40.2	9.4	54.5	49.7	61.4	56.0	53.5	98.4
Suspended-Sediment Conc.	92.7	46.0	15.4	19.2	44.6	108.1	77.3	134.9	185.3	389.9	438.3	306.6
Suspended-Sediment Discharge	8.80	3.98	1.56	2.01	4.82	2.74	11.33	18.04	30.60	58.73	63.08	81.16
Date	6-15-82											
Stream Discharge	173.6	175(E)	175(E)	114.3	93.0	29.0	145.2	150(E)	150(E)	150(E)	150(E)	300(E)
Suspended-Sediment Conc.	26.8	13.9	15.8	14.9	29.4	136.0	63.1	160.2	204.4	171.9	154.3	85.7
Suspended-Sediment Discharge	12.52	6.54	7.44	4.58	7.35	10.61	24.65	64.64	82.48	69.36	62.26	69.48
	-----	Mean	-----	Mean	-----	Mean	-----	Mean	-----	-----	Mean	-----
Stream Discharge	37.9	34.4	34.8	27.7	24.6	7.4	35.4	34.6	39.8	40.6	40.0	90.6
Suspended-Sediment Conc.	35.0	18.7	16.5	16.1	21.6	101.0	41.9	91.5	95.1	120.5	125.7	86.0
Suspended-Sediment Discharge	3.46	1.80	1.48	1.21	2.01	2.82	5.90	14.00	17.93	20.22	19.79	27.24

Note: (E) indicates an estimated flow. Conditions did not allow measurement.
*Minimum 2.5 mg sediment weight was not obtained in sample during analysis. Flagged values are "best guess" approximations. Site 11 was not yet established in August, 1981 and monitoring was not performed.

Appendix B. Approximate Stream Mileage and Channel Slope

Between Big Pipestone Creek Sample Sites

Stream Reach Between	Approximate Stream Mileage	Approximate Channel Slope (ft./mi.)
Site 00 and Site 01	2.8	50
Site 01 and Site 02	0.7	36
Site 02 and Site 03	0.7	29
Site 03 and Site 04	1.5	23
Site 04 and Site 06	0.6	25
Site 06 and Site 07	2.1	18
Site 07 and Site 08	2.8	12
Site 08 and Site 09	1.3	15
Site 09 and Site 10	1.3	12

Appendix C. Net Change (tons/day) in Suspended-Sediment Discharge

Between Sample Sites. April-June 1982

Stream Reach	Net Change (tons/day) in Suspended-Sediment Discharge			
	4-21-82	5-20-82	6-15-82	Mean
00 to 01	+1.0	-4.8	-6.0	-3.3
01 to 02	-1.2	-2.4	+0.9	-0.9
02 to 03	-0.04	+0.4	-2.9	-0.8
03 to 04	+0.2	+2.8	+2.8	+1.9
04 to 06 (including load contributed by 05)	+1.9	+6.5	+17.3	+8.6
04 to 06 (excluding load contributed by 05)	-1.5	+3.8	+6.7	+3.0
06 to 07	+11.1	+6.7	+40.0	+19.3
07 to 08	-7.4	+12.6	+17.8	+7.7
08 to 09	-0.4	+28.1	-13.1	+4.9
09 to 10	+1.1	+4.4	- 7.1	-0.6
10 to 11	+0.2	+18.1	+7.2	+8.5

Appendix D. Net Change (tons/day/stream mile)

in Suspended-Sediment Discharge Between Sample Sites. April-June 1982

Stream Reach	Net Change (tons/day/mile) in Suspended-Sediment Discharge			
	4-21-82	5-20-82	6-15-82	Mean
00 to 01	+0.40	-1.8	-2.3	-1.2
01 to 02	-1.8	-3.4	+1.3	-1.3
02 to 03	-0.1	+0.6	-4.1	-1.2
03 to 04	+0.2	+1.9	+1.8	+1.3
04 to 06 (including load contributed by 05)	+3.1	+10.8	+28.8	+14.3
04 to 06 (excluding load contributed by 05)	-2.5	+6.3	+11.2	+5.0
06 to 07	+5.3	+3.2	+19.0	+9.2
07 to 08	-2.6	+4.5	+6.4	+2.8
08 to 09	-0.3	+21.6	-10.1	+3.7
09 to 10	+0.8	+3.3	-5.5	-0.5
10 to 11	+3.4	+2.7	+10.6	+5.6